TECHNICAL MEMORANDUM

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The use of spectrally filtered products in medium range weather forecasting

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ABSTRACT

The effects of smoothing upper air height and temperature forecast fields in the medium range are studied for the 850 mb temperature and the 500 mb geopotential. Objective verification shows that the optimal degree of smoothing depends on the forecast range and is found to be around T15 for day 4, between T10 and T12 for day 5, approximately T8 for day 6 and below T8 for day 7.

The filtered products give better results when used as predictors in statistical interpretation schemes. Synoptic evaluations provide evidence that the smoothed height and temperature fields afford the best guidance to forecasters for the description of the general flow pattern and the prevailing weather type, in the later phase of the medium range. Possible ways of presenting smoothed forecast guidance to the forecaster are discussed.

1. INTRODUCTION

Long operational experience has indicated, and objective verification has confirmed, that the large scale atmospheric pattern has a higher predictability than the smaller scale features. ECMWF verification results show, for instance that a preset limit, i.e. the anomaly correlation of .6, is at present reached between 6 and 9 days for wavenumbers 1-3, at approximately four days for wavenumbers 4-9 and between 1 and 3 days into the forecast for wavenumbers 10-20.

For the purpose of weather forecasting in the later stages of the medium range, it should therefore be possible to predict the general weather type out to almost ten days, if it is dependent only on the configuration of the longest atmospheric waves.

In this paper the effect of smoothing upper air height and temperature both in time and space, will be discussed. Objective verification results will be presented, from which the optimal degree of smoothing for particular forecast times, can be determined.

The application of smoothed forecast fields in medium range forecasting will be studied by offering these parameters as predictors in a statistical interpretation scheme and also by synoptic assessment of the smoothed products.

Finally, the application of smoothed forecasts will be discussed. Suggestions on possible ways of presenting forecast guidance for the later stage of medium range will be made based on smoothed products.

2. DELINEATION OF THE LONG WAVE PATTERN

In the 1920s, German meteorologists discovered the connection between large scale flow pattern and the prevailing weather type. They tried to describe the "Grosswetterlage" objectively, and made it a forecasting tool. Since then, many different approaches have been taken to the delineation of the large scale flow pattern on weather charts, from simple time averaging to space smoothing.

At the US Navy central forecasting office in Monterey, Fourier filtering has been applied to 1000 and 500 mb height fields since the late 1960s. Forecasters are provided with both the smoothed and the full scale model output. According to reports from Monterey, the smoothed fields are much the preferred forecast tool among the forecasters, especially for ship routing forecasts five days ahead.

2.1 Time averaging

Constructing time mean charts over several consecutive days has for a long time been the practical approach to creating a picture of the large scale flow. The preferred time span for averaging has been five days. (ECMWF also issues the forecasts for 500 mb height fields as time mean fields for days 6-10 as an experimental product to its Member States).

Time averaging has some known deficiencies of which the user must be aware. While it leaves the stationary part of the flow intact, it will remove all the non-stationary contributions. Since the long waves are often stationary or quasi stationary features, time averaging has a desirable effect and helps to delineate the long wave pattern, except in cases when there are significant changes in the positions and intensities of the zonal flow and long wave pattern. Trough movements, which may be as large as 20-40 degrees in an east-west direction, and are mostly well predicted, are more or less lost in a five day time average.

2.2 Space smoothing

In contrast to time averaging, smoothing in space at individual steps does not obliterate the positions of the longest waves and is therefore more useful for studying the large scale pattern. There exist various different methods of smoothing the atmospheric fields, from simple averaging processes to filtering in the Fourier domain or on the sphere. In the latter case, the best possible truncation must be found.

The spectral formulation of the ECMWF pôst-processed fields facilitates the presentation of a smoothed forecast field by selecting only the long wave part of all the 63 spectral components. Figs. 1 and 2 show, as an example, the same 850 mb temperature and 500 mb geopotential charts composed of 6, 16 and the full set of 63 spectral components (T6, T16 and T63 respectively).

Six spectral components give a very smooth, but still realistic picture of the long wave pattern. Increasing the number of components to 16 makes the pattern more detailed by including the largest synoptic transient waves.

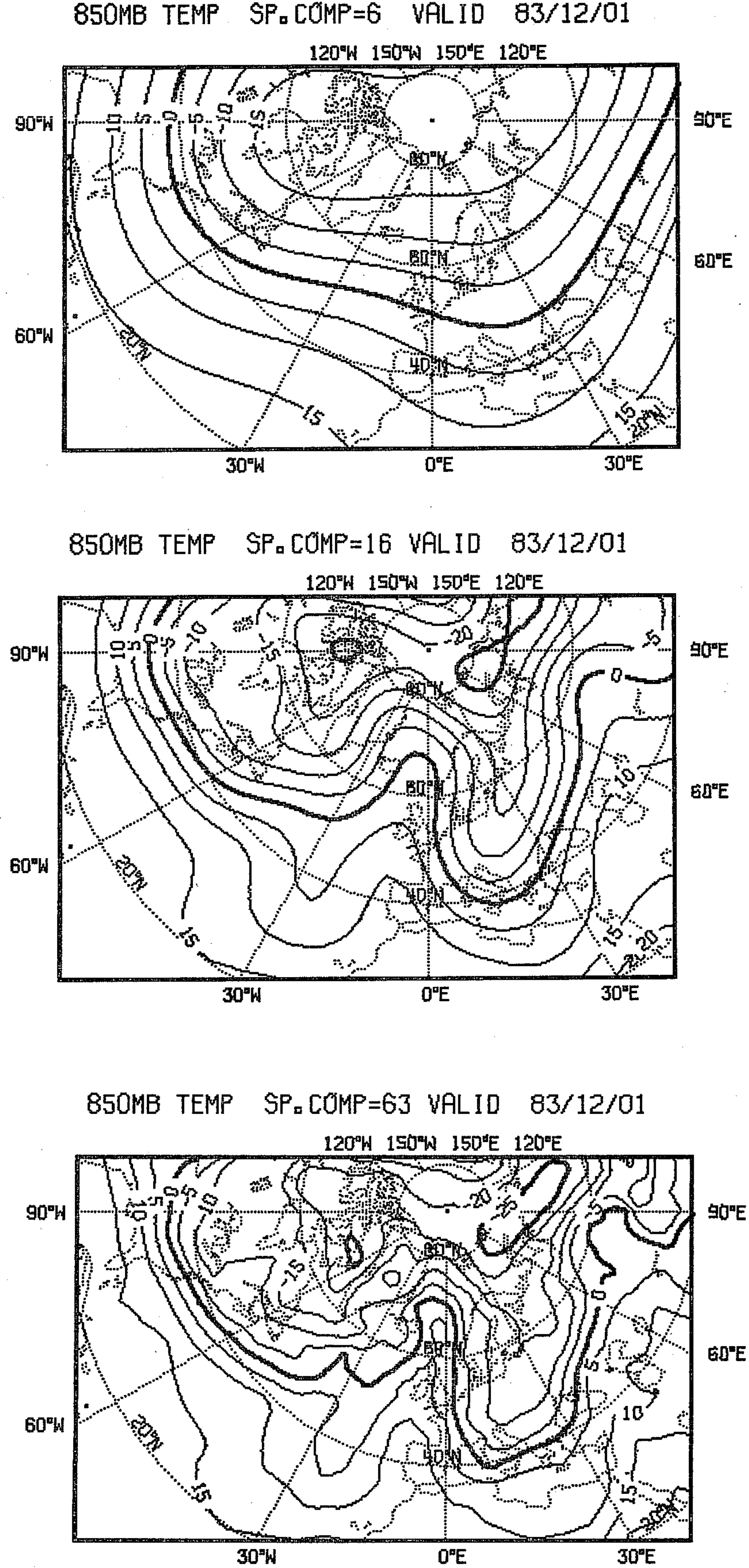


Fig. 1 An analysis of 850 mb temperatures from 1 December 1983, shown with truncations at T6, T16 and T63

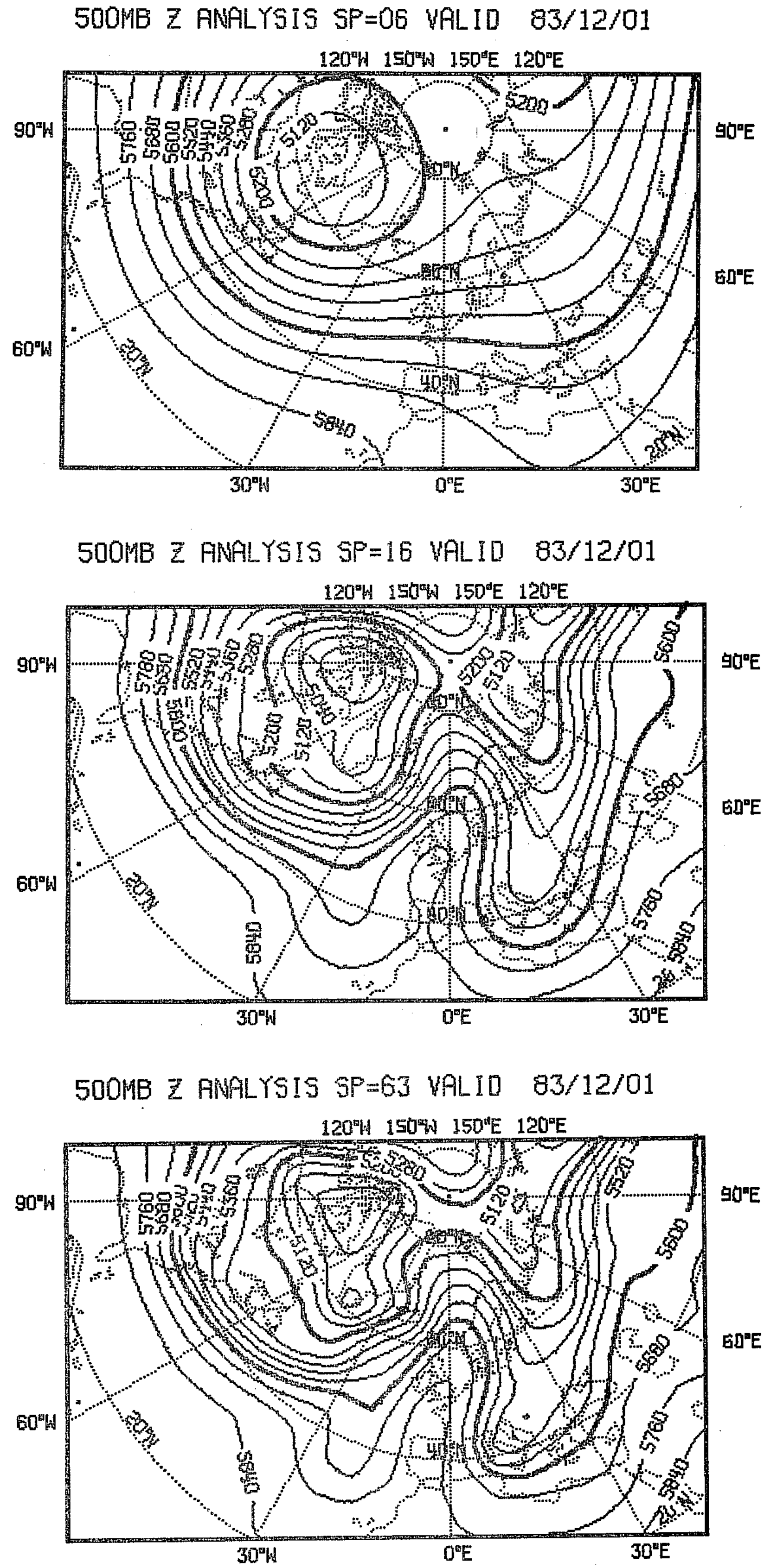


Fig. 2 500 mb geopotential analysis from 1 December 1983, shown with truncations T6, T16 and T63

2.3 The optimal smoothing

In a series of tests, the relation between different grades of smoothing and the description of the long-wave pattern in the atmosphere was established. The operational ECMWF forecasts for +96, +120, +144 and +168 hours from June-December 1983 with different degrees of smoothing have been verified against non-smoothed analysis fields. The parameter chosen for the tests was the temperature at 850 mb, which describes both the synoptic and large scale pattern and is a useful predictor for both subjective and statistical interpretations of forecast products. Additional tests have also been carried out with the geopotential at 500 mb.

Two verification areas were chosen, one over north western Europe, the other a belt from Portugal to Turkey, each divided into 12 gridpoints (Fig.3).

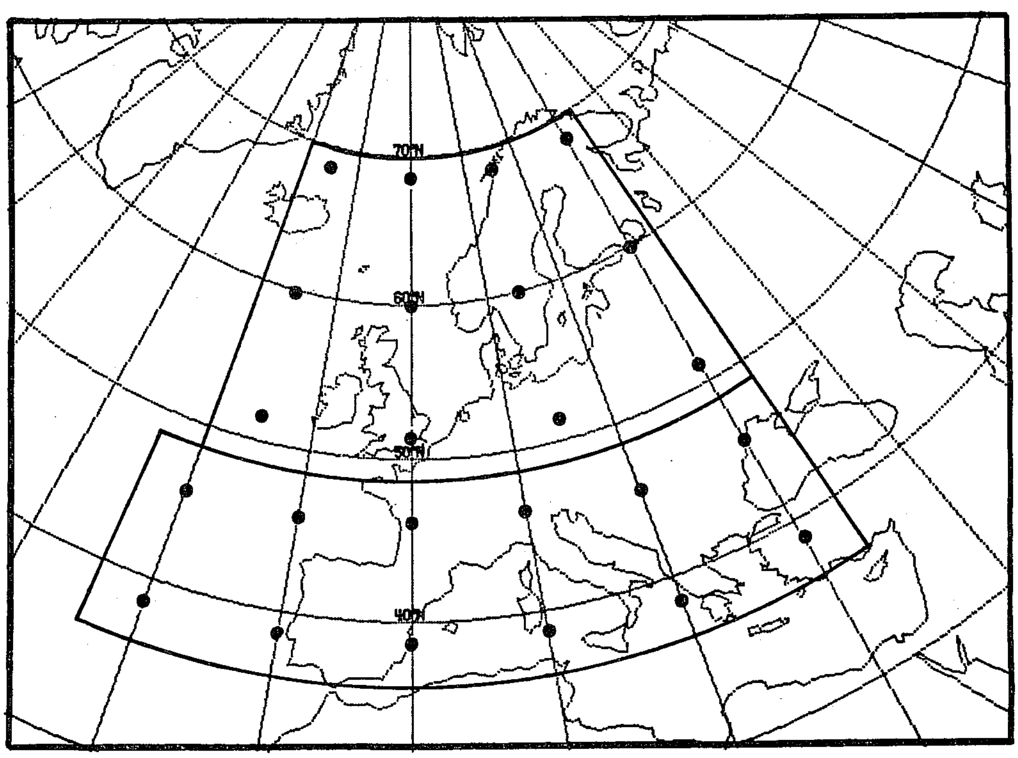


Fig. 3 The verification areas and the selected gridpoints

2.3.1 Results of the verification of 850 mb temperatures

The verification studies for the northern European area show a rather close relationship between the standard error of the forecast and the optimal smoothing (Fig. 4). For the southern European part the relationship was less obvious, but still recognisable (Fig. 5).

The verifications for +120 h and +144 h are given below (Fig. 4) and show an optimal truncation of 10-12 spectral components for a +120 h forecast and approximately 8 spectral components for a +144 h forecast. The results indicate that the optimal smoothing is dependent on the forecast length but not on the geographical location.

Filtering resulted in a considerable improvement in the verification scores (standard deviation of error and correlation) for both northern and southern Europe. The optimal smoothing, which is seen as a distinct minimum in the diagram, brings the error for a +144 h forecast below the error of the operational forecast for +120 h over northern Europe, almost down to the operational +120 h forecast for southern Europe. The same feature can be seen in the correlation scores(not shown here).

For very high truncations ($<$T6) any improvement is lost. For less strong truncations ($>$ T15) the scores approach asymptotically the scores of the routine forecast asymptotically.

The verification for +96 h shows an optimal truncation around T15, though with only a minor reduction of the errors (approximately .1 degree).

For the 168 h forecasts the optimal truncation seemed to be below T8 with a reduction of the errors of the order of half a degree, almost reaching the standard of a non-filtered +144 h forecast. This could still be considered to be on the limit of useful predictability.

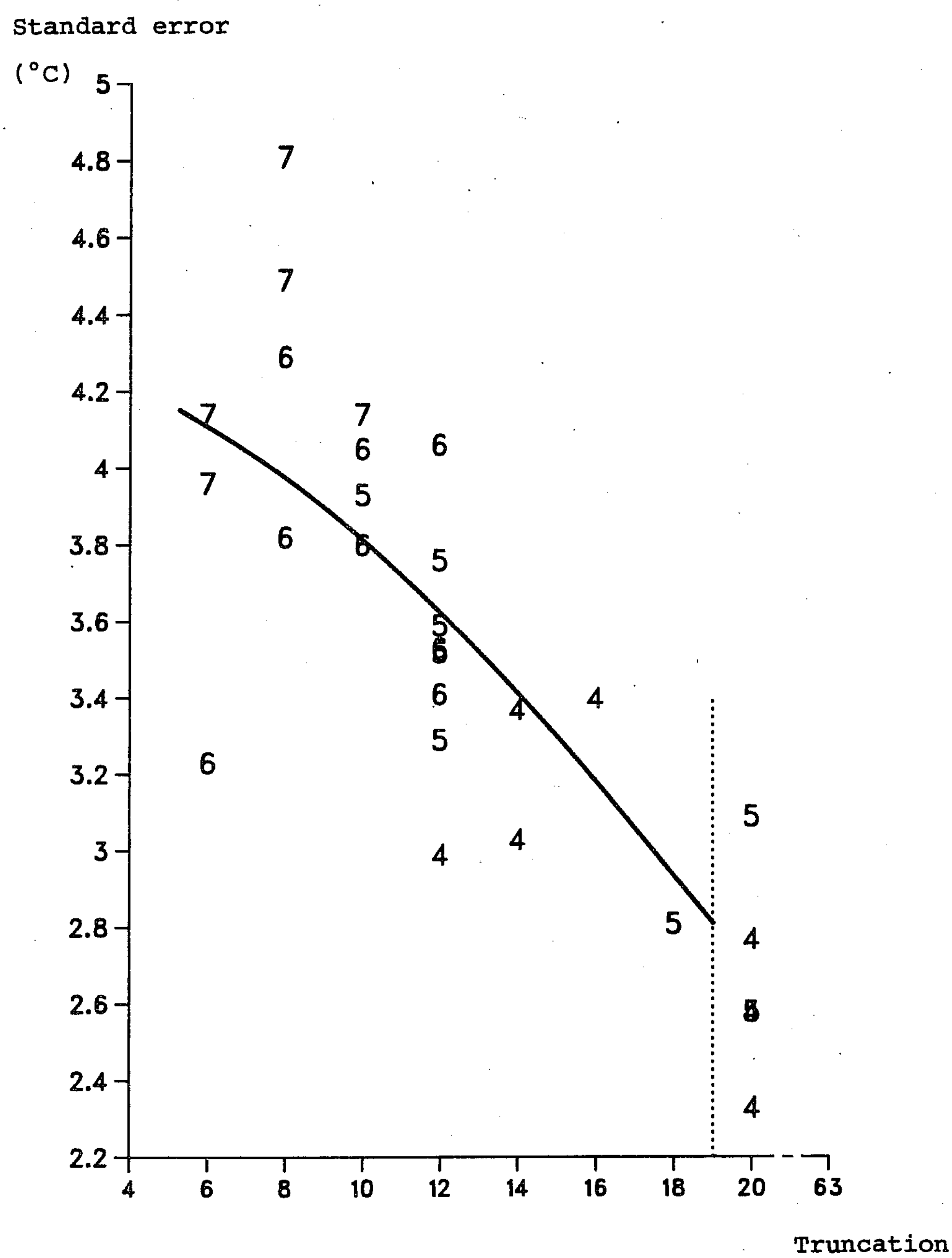


Fig. 4 The relation between the optimal smoothing (x-axis) and the corresponding standard error (y-axis) for temperature in 850 mb temperatures over northern Europe June-December 1983. Digits in the figure indicate the forecast length (e.g."6" stands for a 6-day forecast).

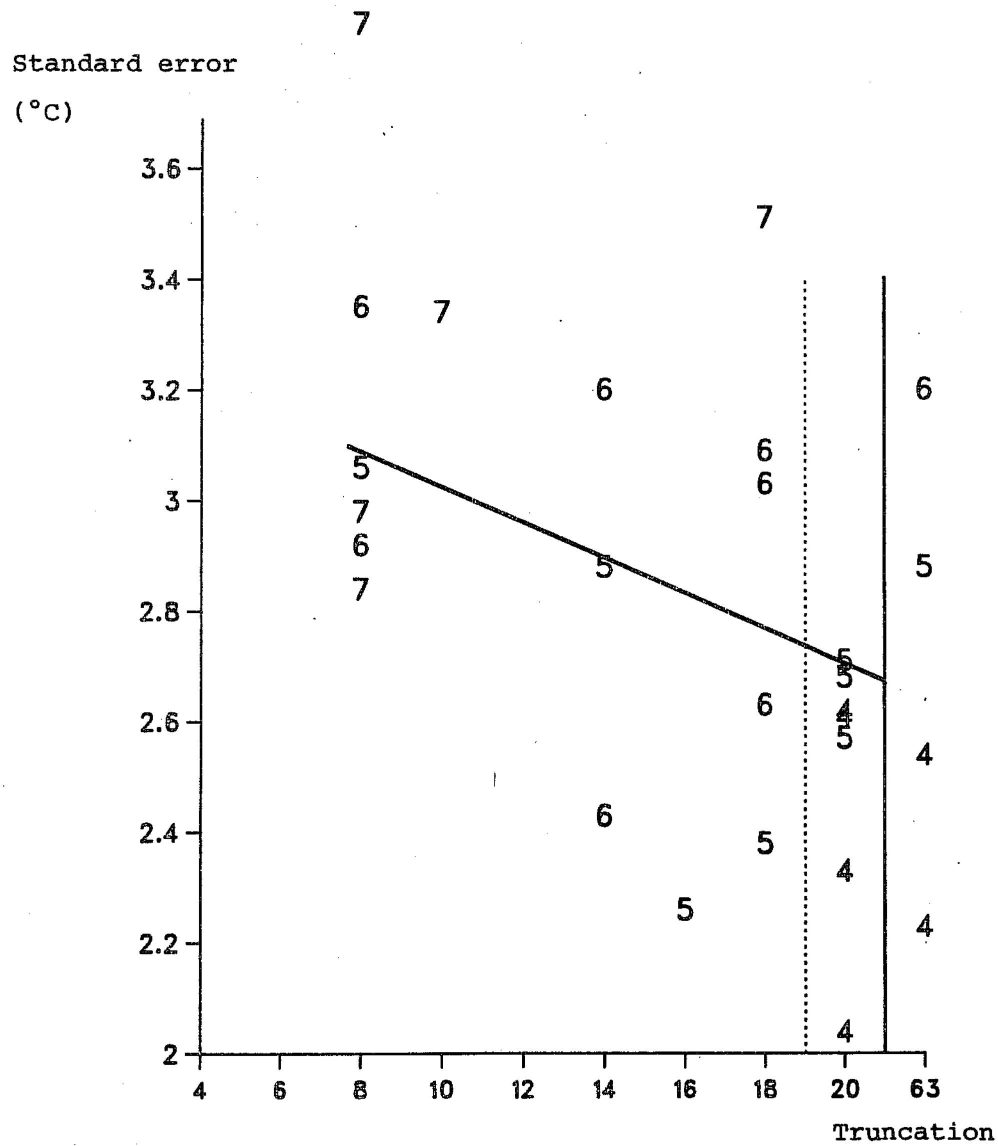


Fig. 5 Same as for Fig. 4 but for southern Europe.

Fig. 6 shows the results for the 5- and 6-day forecasts for northern Europe. The thicker curves are the standard deviations of error and correlation (deviation from operational non-filtered analysis) for September-December 1983. The thin, dashed lines correspond to the mean standard deviation of error for the non-filtered ECMWF forecasts.

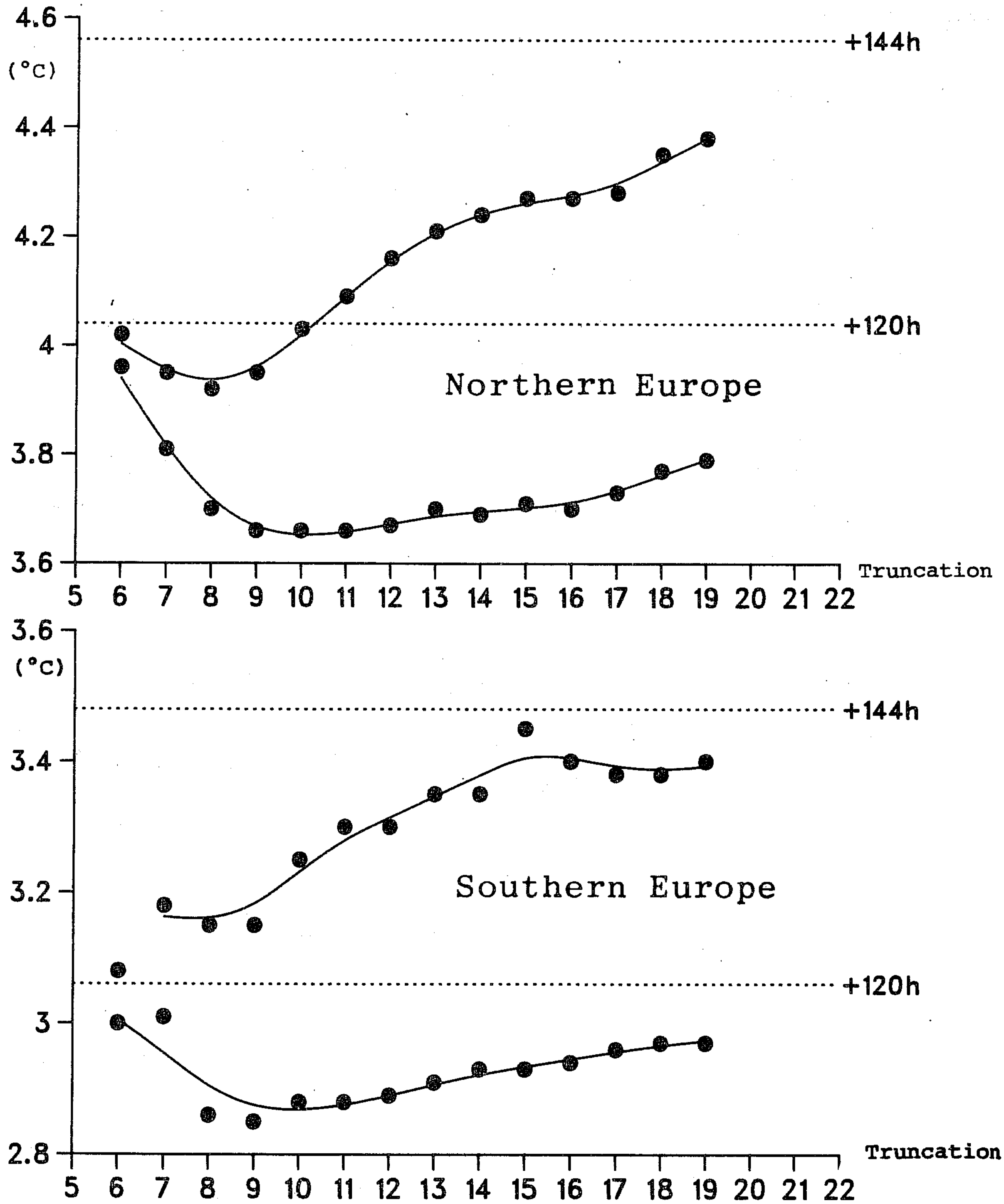


Fig. 6 Relation between the truncation T6 to T19 and the standard deviation of error of +144h and 120h forecasts of 850 mb temperatures over northern and southern Europe September-December 1983. The operational model's errors are shown as dashed horizontal lines.

2.3.2 Verification of smoothed 500 mb geopotential fields

500 mb forecasts of height have been verified for the same areas for +120 and +144 hour forecasts covering the period September-December 1983. The optimal truncation varied between 10 and 12 for +120 hour forecasts and 8 for +144 hours (Fig. 7).

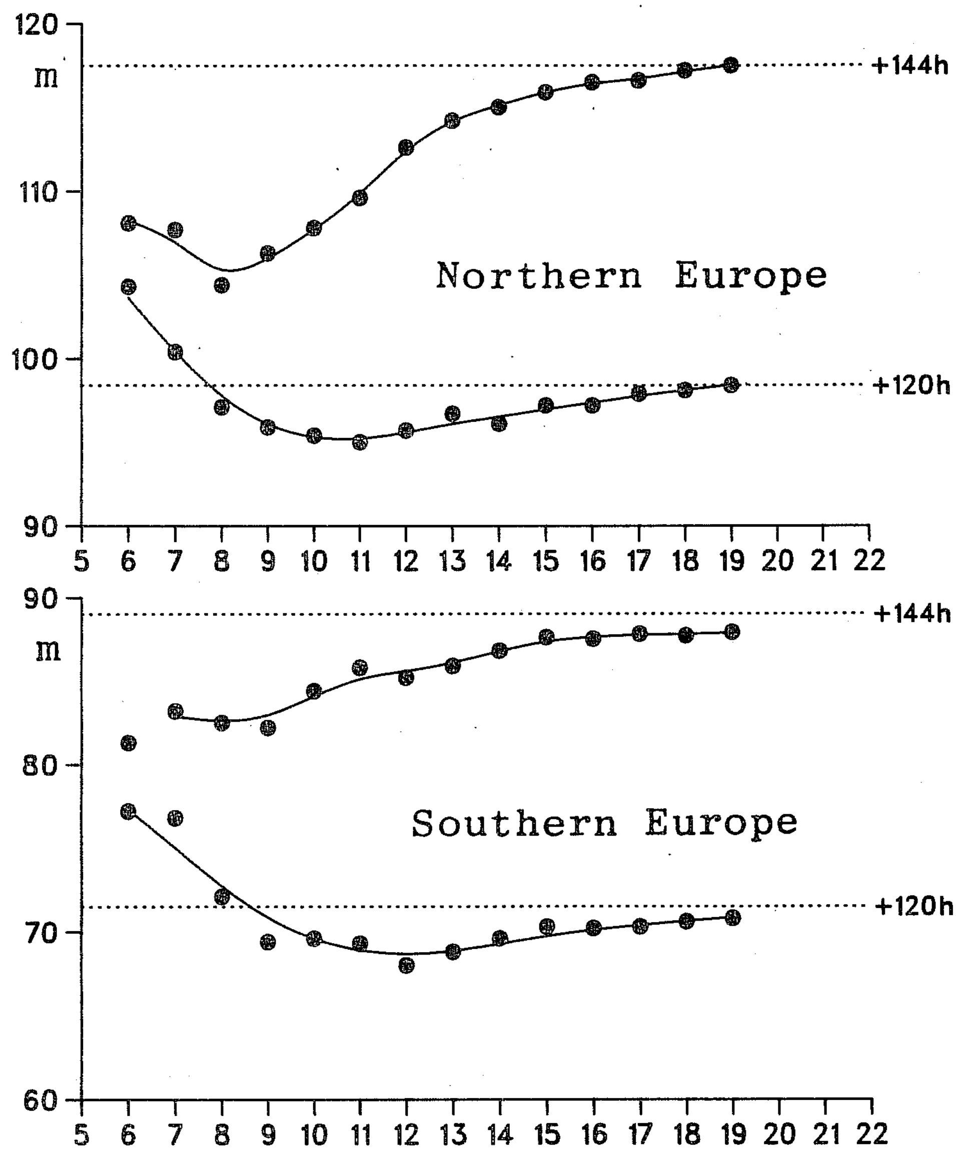


Fig. 7 Same as Fig. 6 but for 500 mb geopotential

The scores of the +144 h forecast compared with the scores for the operational, non-filtered +120 h forecast, showed an increase of about half a day, somewhat more for northern Europe, somewhat less for southern Europe. There seemed to be no great variation between northern and southern Europe.

3. APPLICATION OF FILTERED FORECASTS

The usefulness of smoothed forecasts has been evaluated in several tests.

3.1 Statistical interpretation

Two experiments making use of the filtered 850 mb temperature forecasts in an objective statistical scheme applying the multiple linear regression technique were carried out. The aim was to predict the temperature observed in Hannover, Germany, at 12 GMT during September-December 1983.

The predictors offered were:

Height	1000,850,700,500 mb	Valid at D+5 and D+6
Temp	850,700,500 mb (non-smoothed)	
u,v	850 mb	
thickness	850/700 1000/500 mb	

The derivation of the prognostic equation was then repeated by offering the predicted 850 mb temperature truncated at 10 (+144h) and 12 (+120h) spectral components as an additional predictor. The smoothed 850 mb +120h temperature forecast using 12 spectral components stood out as the best single predictor with a correlation of .71 and a standard error of 4.3 degrees, followed by the relative topography 1000/500 mb and the unsmoothed 850 mb temperature forecast with correlations .65 and .60 respectively and standard errors 4.7 and 5.0 degrees respectively.

The experiment was repeated for a +144 h forecast truncated at T10. With a correlation of .71 and a standard error of 4.4 degrees the smoothed field once again stood out as the best predictor, followed by the relative topography 1000/850 mb and the unsmoothed forecast.

3.2 The synoptic evaluation of filtered charts

The use of filtered and un-filtered charts in an operational forecast has been assessed. The results indicate that the filtered maps may help the forecaster to concentrate on the large scale flow pattern in later stages of medium range forecasting (> 4 days).

- Details in the forecasts which have a lower predictability do not distract the forecaster.

- The forecaster can easily get a picture of the large scale pattern and detect important signs of changes in the long wave pattern.

- It is easier for the common systematic errors of the model to be recognised and in many cases they can be adjusted for, e.g. the troughs often displaced to the east over the Mediterranean area, or the too southerly position of the westerly jetstream over central Europe.

- Since the long waves have a predictability of 6 to 9 days, the filtered maps will generally appear more consistent from one forecast run to the other.

Though verification shows that the optimal truncation is dependent on the forecast length, a variable filtering is not desirable because of practical inconvenience, e.g. comparing different forecast periods or different forecasts for the same time period. A variable truncation would also make any statistical interpretation much more complicated.

Since the period which seems to be of most interest for the time being, considering also the present quality of the model, is the 5-7 day period, for which the truncation on average lies around T10, this truncation also appears to be the one of most practical value, making the above-mentioned comparisons and interpretations possible.

In real operational use filtered maps will always be used together with the non-filtered forecasts (as is the practice in the US Navy) since the "lost" details, though not correct in time and place, might give valuable information about the weather events that could take place (e.g. small secondary depressions, sharp fronts, orographic effects etc), i.e. information about the variance in the forecast.

4. PRESENTATION OF POSSIBLE PRODUCTS FROM ECMWF

The ways of presenting these new products are of essential importance to the medium range forecaster. The means should readily provide an overview and facilitate interpretation. They should, if possible, be directly related to the parameters which are used in the forecasts issued to the general public.

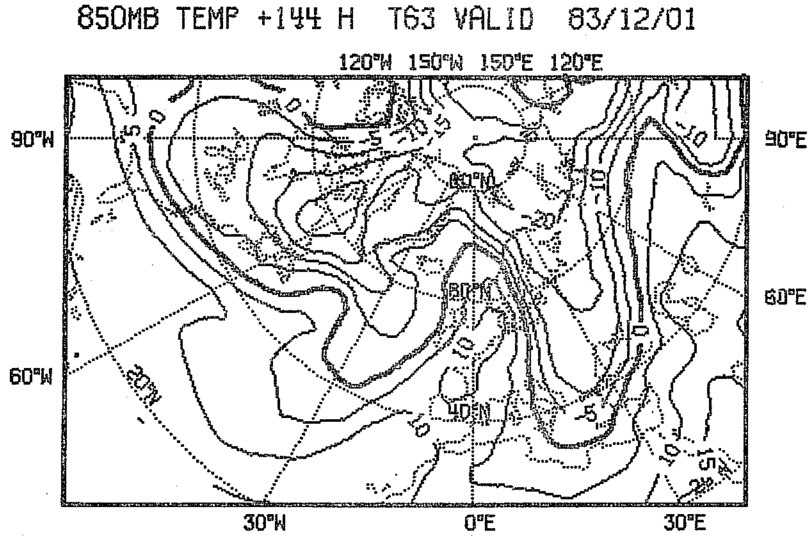
With examples from the ECMWF +144 hour forecast truncated at T10 from November 25 1983, verifying on December 1st, the different types of products will be shown and suggestions made for their use.

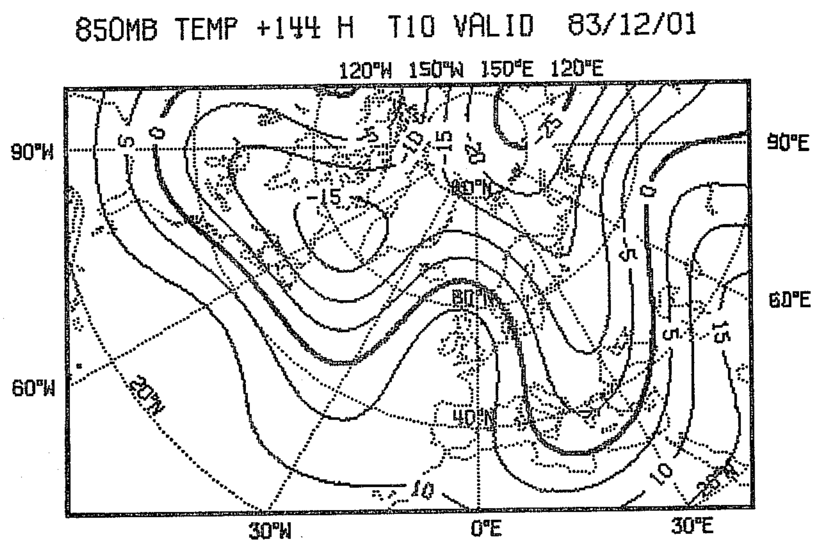
4.1 850 mb temperature charts, truncated at 10 spectral components (Fig.8)

The non-filtered forecast shows a tongue of warm air moving eastwards over northern Europe, while a cold trough penetrates south-eastern Europe. Filtering does not change the overall pattern, but weakens the temperature gradients over Scandinavia. This is a signal to the forecaster that they are of lesser scale and less reliable. The verification reveals that the warm air was more slowly advected and the gradients weaker.

4.2 Trough-ridge diagrams from filtered forecast fields (Fig. 9)

These Hovmoeller-diagrams show in a very simple and practical way the general features and movements in west-east direction (approximately along the zonal flow). The y-axis indicates time in days and the x-axis the longitude. Isolines are drawn for the north-south mean of the filtered 850 mb temperature field. These two trough and ridge diagrams are computed between 35-55 N and 45-65 N and filtered by a Fourier analysis, filtering away wavenumbers $>$ 9.





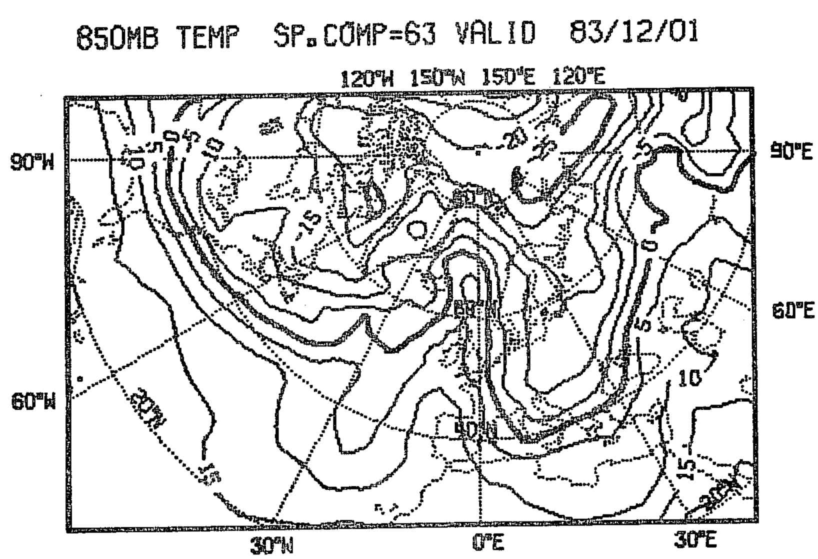


Fig. 8 850 mb temperatures in a +144h forecast, truncated at T63 (above) and T10 (centre) and verifying chart in T63 valid 1 December 1983 (below).

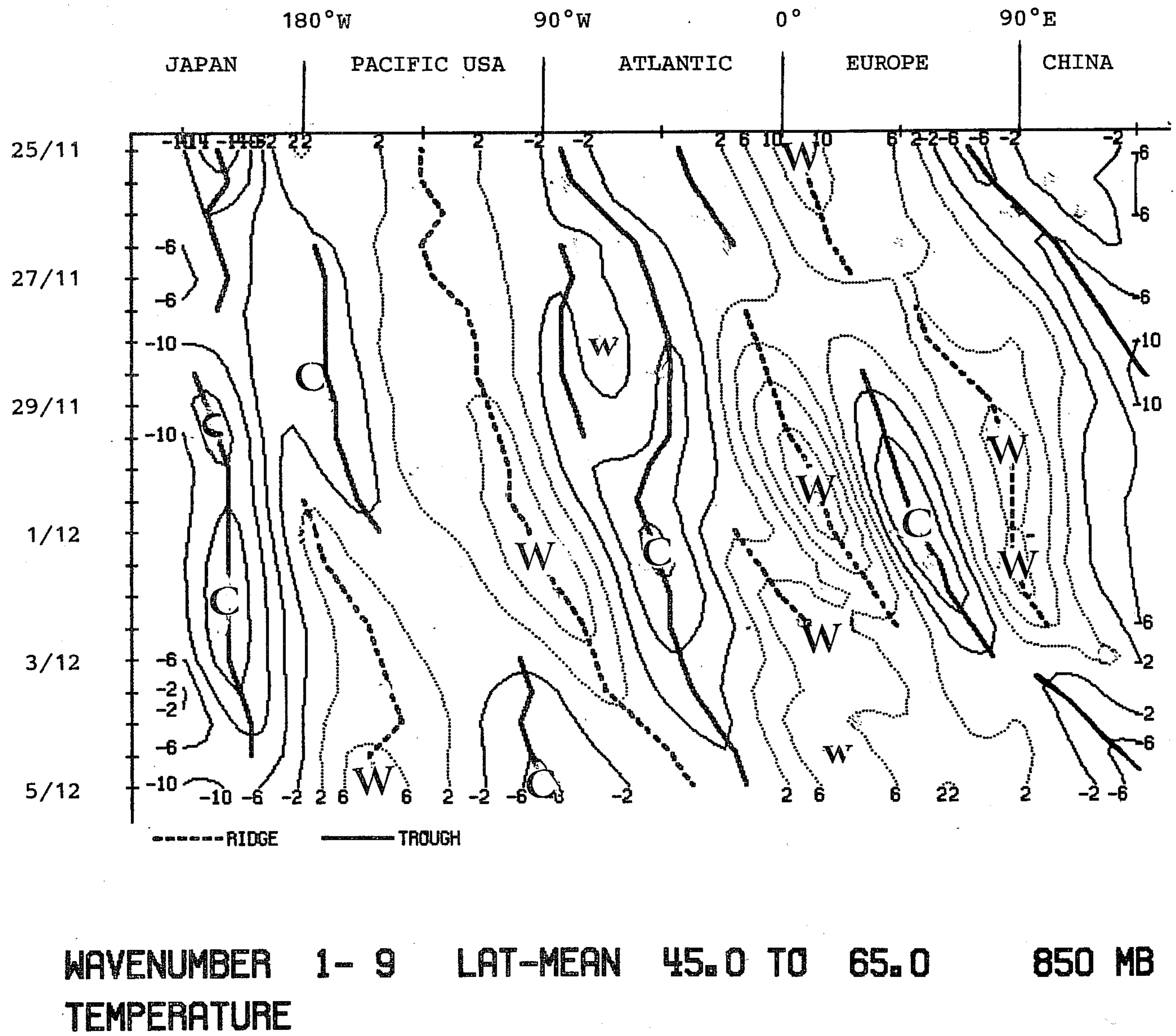


Fig. 9 Hovmoeller diagrams showing the ECMWF 10 day forecast from 25 November 1983 of 850 mb temperature. 25 November - 5 December 1983 (above) and verification (below). The warming over W. Europe and cooling over E. Europe forecasted on 1 December are clearly to be seen. The warm air remains almost stationary, while the cold air moved eastwards.

In both diagrams the formation of the warm or cold tongues are clearly visible from the 28th onwards.The eastward movement of the cold air over eastern Europe is clearly seen, as is the stationary position of the warm air over western Europe.

4.3 Forecast maps truncated at T10 showing the deviation from non-smoothed climate fields (Fig.10)

It is also possible to present the filtered temperature forecasts as deviations from normal conditions. The quality of the forecasts is not changed but is in agreement with the medium range forecasting practice in some Member States which provide the public and users with deviations from normal, rather than absolute values.

4.4 500 mb geopotential charts, truncated at 10 spectral components (Fig. 11)

In this example, the fast moving troughs in the westerlies from Canada towards northern Europe are filtered away and, as the verification shows, were not accurate due to phase errors.

The sharp,fast moving trough over the Mediterranean is of a smaller scale and is filtered away, leaving only the trough over eastern Europe as the only important large scale feature to be considered.

4.5 Trough-ridge diagrams of 500 mb geopotential (Fig. 12)

The phase error is not evident in the trough-ridge diagrams since they are computed over 20 latitude degrees which results in a certain north-south smoothing.

Considering only the large scale positions of ridges and troughs at 500 mb and the cold and warm tongues at 850 mb, it would have been possible to make a useful weekly forecast of the general weather one week ahead, for northern Europe the outlook could have been extended even further.

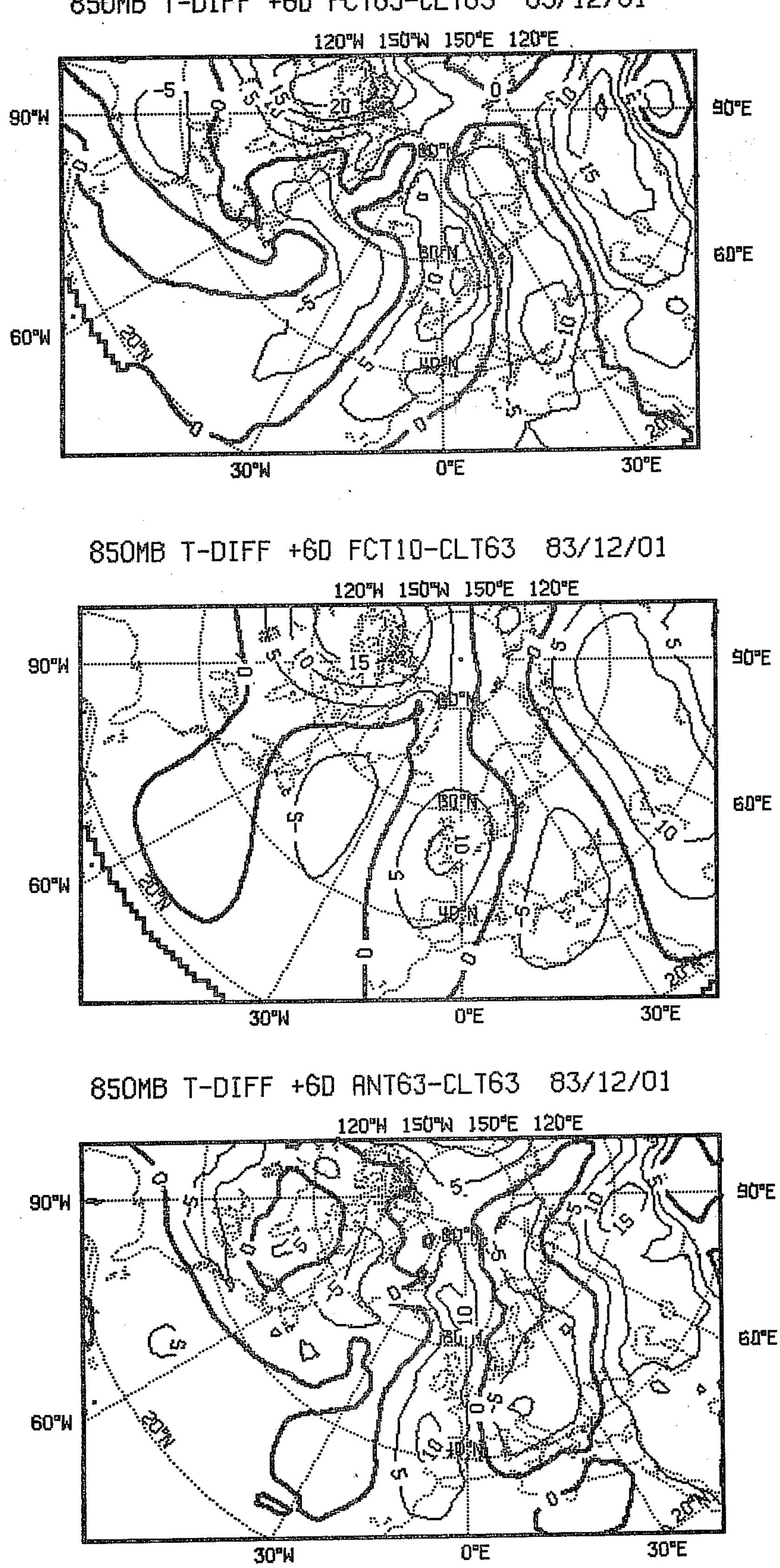


Fig. 10 850 mb temperature forecast +144h truncated at T63 (above) and T10 (centre), shown as deviations from climate (T63), and verification valid 1 December 1983 (below).

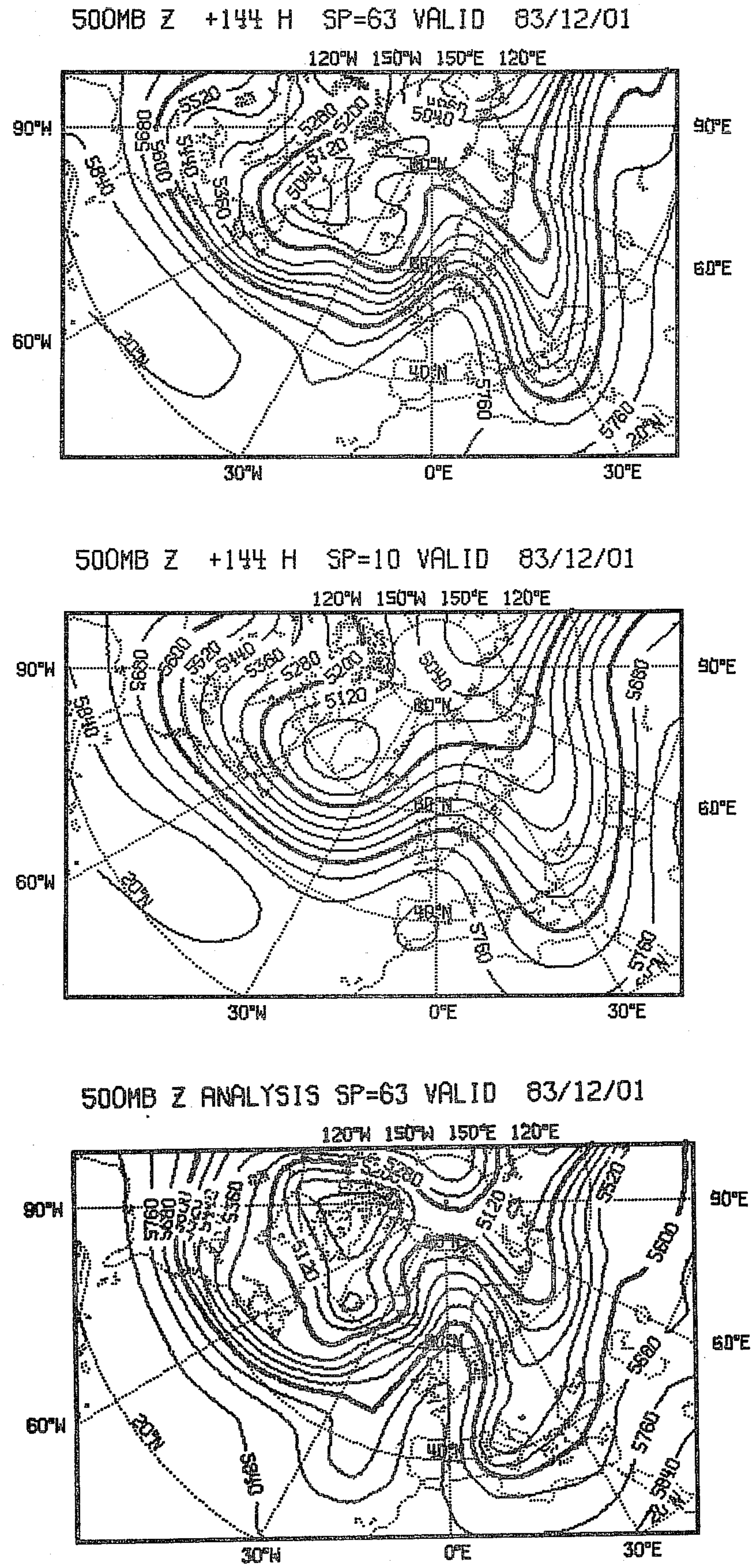
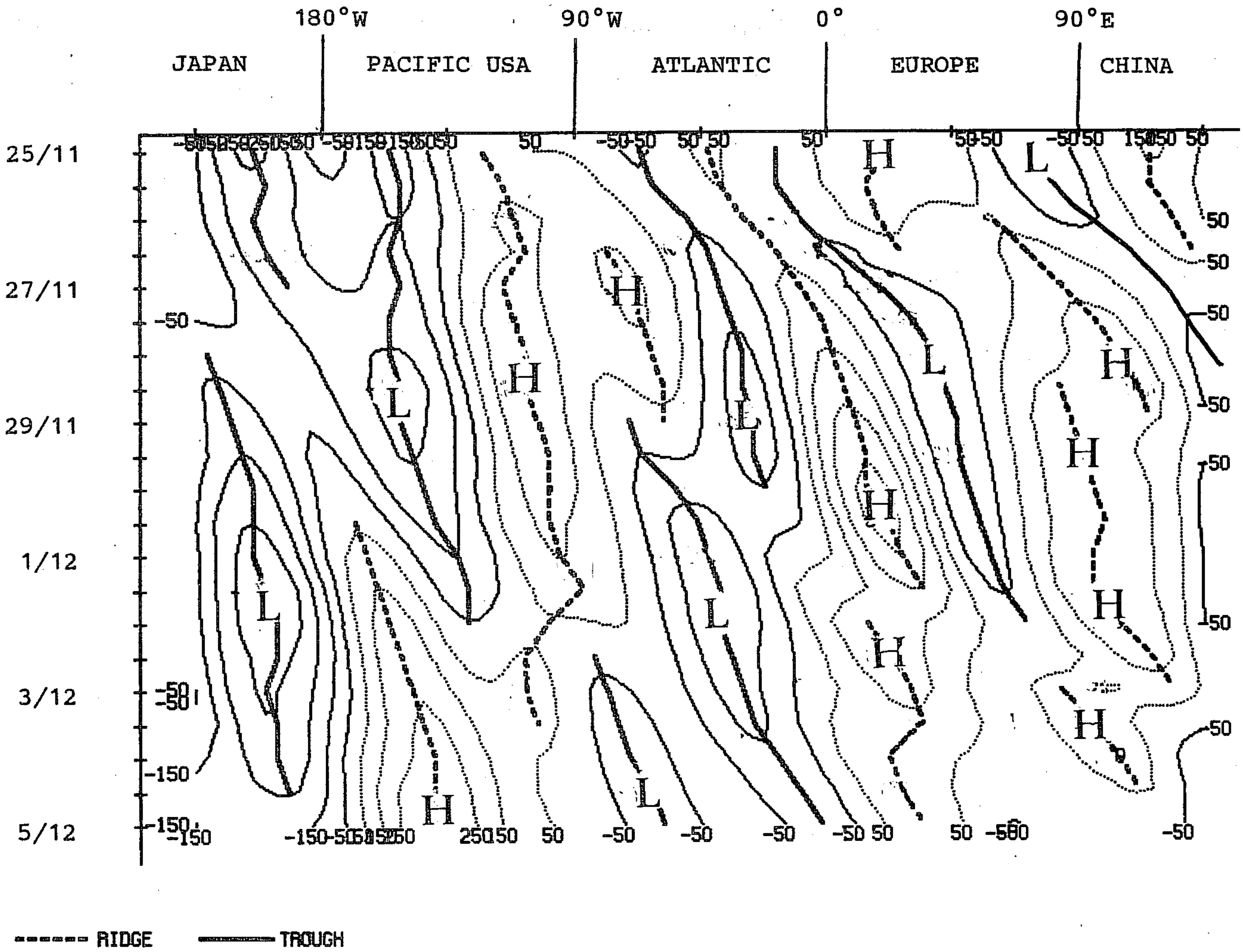


Fig. 11 As Fig. 8 but for 500 mb potential



WAVENUMBER 1- 9 LAT-MEAN 45.0 TO 65.0 500 MB
GEOP. HEIGHT

Fig. 12 Hovmoeller diagrams of the ECMWF 10 day forecast of 500 mb geopotential (25 November 1983) as deviation from latitudinal mean (above) and corresponding verification (below). The stationary and transient movements are clearly to be seen.

5. SUMMARY

The effects of smoothing upper air height and temperature fields have been studied for the 850 mb temperature and the 500 mb geopotential. Space filtering for individual forecast steps is the preferred tool for depicting the large scale flow pattern in the later phase of the medium range. i.e. after day 5. Objective verification has shown that the optimal degree of smoothing depends on the forecast range and is found to be around T10 for days 5 and 6. For continuity, the same truncation should be applied for adjacent forecast days, when presenting the user with smoothed products.

The filtered products give better results when used as predictors in statistical interpretation schemes. Synoptic evaluations give evidence that the smoothed height and temperature fields are a useful product in the later stages of the medium range and provide the forecaster with the best guidance for the description of the general flow pattern and the prevailing weather type, as the smaller scale features, which have low predictability in this forecast range, have been removed.

Possible ways of presenting smoothed forecast guidance to the forecaster have been discussed and anomaly charts and/or trough-ridge diagrams have been suggested, although the most suitable form of presentation would depend on the forecasting practices in each Member State.